Independent learning as class preparation to address deficiencies in secondary educational background and to foster student-centred learning in first-year engineering students

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In first-year engineering students, a common teacher-centred, passive learning and deficient secondary educational backgrounds are often observed. However, there is a problematic difference whether the individual background is vocational education and training (VAT) or baccalaureate. This implies an educational need to level up these backgrounds, together with a more student-centred, active learning. As a possible practical remedy, an approach of independent learning before the class was implemented, as in a flipped classroom. To this end, students were requested to study the topic scheduled for the next class independently as an out-of-class activity or 'homework', by using sources suggested (handbooks and web pages). At first, this task was not monitored. In a second phase, the task was monitored by a handwritten summary delivered before the class. Although some differences surfaced depending on a student's educational background (VAT vs. baccalaureate), but also in repeaters vs. non-repeaters, a questionnaire survey showed that this type of homework was perceived as fostering a better understanding of theory in class and a more appealing class, but only if it was controlled as described. A quantitative comparison of final-exam grades and homework grades reveals a better performance by most students with sufficient homework, although with some limitations.

Keywords: secondary educational backgrounds; independent learning; life-long learning; student-centred learning; flipped classroom

Introduction

At our engineering colleges, at least in Spain, a combination of two handicaps is observed in first-year students – a deficient secondary educational background and teacher-centred passive learning.

A deficient educational background is confirmed by the relatively poor results from the OECD Program for International Student Assessment (PISA), which evaluates students in many countries. The PISA indicates that the Spanish students are performing below the average for the European Union Member States (OECD 2016, OECD 2017, Sulkunen 2013). The educational background is even poorer in students with vocational education and training (VAT) in Spain and other industrialized countries, being a major factor for the students' drop-out in tertiary education (Lassibille and Navarro Gómez 2008; Eichhorst et al. 2012; Eichhorst et al. 2015). Therefore, there is a need to level up the students' knowledge when they join a university degree (Pico et al. 2017).

Teacher-centred passive learning in secondary education was previously observed by Smeets and Mooij (2001) in Spain and four other European countries in which teachers tended to maintain a teacher-centred learning environment instead of acting as coaches (we revert to this issue in the next section 'Theoretical framework'). In addition, Sangrà (2002) noted the teacher-centred model in traditional Spanish universities. Although a number of years have passed since these studies, first-year engineering classes are often overcrowded, and the situation of teacher-centred learning has not radically improved, frequently leading to passivity as a normal learning attitude (Michel, Cater, and Varela 2009; White et al. 2016), even in online distance education (Smith and Smith 2015). At least in Spain, this handicap is also an obstacle to the process of convergence within European Higher Education Area (EHEA), since the new EHEA curricula are based on the development of skills such as the competence for autonomous life-long learning and students' ability to work outside of class (Bosco and Rodríguez-Gómez 2011).

Both handicaps (lack of mathematics and science literacy background at the secondary-education level, and passive learning attitude) slow the progress of a class tremendously. However, the scheduled physics syllabus should be covered for these freshmen as far as possible, so that they may progress with their engineering curriculum with sufficient scientific knowledge.

The objective of this paper is to report on the students' response to a practical remedial action taken in order to face these handicaps, taking into account the differences in secondary educational background, whenever possible: VAT vs. baccalaureate, and also repeaters vs. non-repeaters. The Spanish baccalaureate can be compared to the French baccalaureate in France or the A Level in England. It is a two-years course after completion of the compulsory secondary education, usually at the age of 16. The scientific level is clearly higher than in the alternative middle-grade VAT, so that in most cases, it is chosen with the idea of entering a university or college.

This remedial action has been implemented by the authors with first-year students of fundamental physics (covering from kinematics up to electromagnetic waves) at their engineering college in Spain – essentially, it consists in an independent or autonomous preparation of each theory class using suggested sources. The next sections are a description of this remedial action in detail, the presentation of its theoretical framework, and the introduction of the study of the students' response under the aspect of perceived usefulness according to a survey. In two further sections, the results of the survey and the complementary results from a comparison between homework grades and exam grades as empirical data are provided and discussed. The final section provides the conclusions.

A remedial action: a special homework to foster independent learning

As a remedial action to the situation described above, a special type of homework was considered, with an essential active-learning component – students should attempt to independently understand and learn the topic scheduled for the next theory class in preparation for that class.

Thus, this autonomous-learning component did not impinge on the necessary in-class hours of instruction (Perdigones et al. 2014), which must not be curtailed on the pretext of autonomous learning, alleging that first-year students have an underdeveloped ability to learn independently.

As a component of the external structure of autonomous learning mentioned by Snodin (2013), students had access through our Digital Campus to a calendar containing the specific topics scheduled for each class (Figure 1) as well as references to sources suggested for viewing the topics independently. Indeed, students in a flipped-classroom approach also want and require clear structures and guidelines (Wanner and Palmer 2015).

Autonomous learning work in preparation for each class

Everyone has to come to class after having studied the topic scheduled according to the following table. In the class itself, only doubts will be clarified, only a summary of the topic will be explained, and activities for a better understanding will be carried out.

The numbering of topics matches that in the document "Recommended sources".

Class of:	*Topic that must have been studied:*
10 September	1: Kinematics
17 September	2: Dynamics
24 September	3: Work and Energy
8 October	4: Systems of Particles and Statics
15 October	5: Rigid Body
5 November	6: Oscillations
12 November	6: Waves – Wave Motion
19 November	6: Waves – Wave Motion (cont.)
3 December	7: Dilation and First law of thermodynamics
17 December	7: First law (cont.) and Second law of therm.

Figure 1. Scheduling of theory topics in the Digital Campus for autonomous learning before each theory class.

For each topic, two types of sources were suggested: a traditional handbook (Figure 2) and web pages (Figure 3). Students could also use any other textbook or Internet source if preferred. Both types of sources were offered because using the new technological tools for learning, although efficient, also has limitations (Houle and Barnett 2008). In addition, many learning materials available online are not essentially different from traditional texts because they do not utilise their potential in terms of interactivity and multimedia (Bosco and Rodríguez-Gómez 2011).

Recommended sources for preparing the classes autonomously:

1.- Text in handbook format:
"Physics for Scientists and Engineers", authors: **Tipler – Mosca**; ed. Freedman and Co.
(Other handbooks by the same author(s) can be also used, after checking the correspondence between chapters and sections).
Remarks: The sections preceded by an asterisk (*) and any proof of a formula are not compulsory if the concepts are understood without the proof.

Topic 1: Kinematics (including Vectors and Vector calculus)

- Chapter 3: Motion in two and three dimensions (except "Relative velocity")

Topic 2: Dynamics

- Chapter 4: Newton's laws of motion
- Chapter 5: Applications of Newton's laws of motion (Sections 5.1 and 5.2)

Topic 3: Work and Energy

- Chapter 6: Work and Energy
- Chapter 7: Energy conservation (Section 7.1, up to formula 7.4)

Topic 4: Systems of Particles and Statics

- Chapter 8: Systems of particles ... (Section 8.1, up to formula 8.5)
- Chapter 12: Static equilibrium ... (Sections 12.1 to 12.3)

Topic 5: Rigid Body

- Chapter 9: Rotation (Sections 9.1, 9.2, 9.3 except "Parallel axis theorem", and Section 9.6)
- Chapter 10: Angular momentum conservation (Section 10.2, and Section 10.3).

[etc.]

Figure 2. Suggestion of a handbook in the Digital Campus as a possible paper source for the task required.

In the first theory classes, this out-of-class activity was presented, together with the suggested sources (both textbooks and Internet pages), as the preparation required for every theory class. So, a substantial first portion of every theory class would always be devoted to clarifying any questions that had arisen during the independent preview of the theory at home. By the second theory class at the latest, every student in class should have realised the necessity of completing this at-home activity before class; otherwise, a substantial portion of the class would be of little practical use and quite boring. Indeed, the rather traditional teacher-centred explanation at the blackboard was restricted to a summarised overview, and the remainder of the class time was primarily devoted to problem solving by the students themselves, Java simulations, quiz questions, etc. In this manner and with the lecturers' continuous reminders, students were encouraged to do the preparatory homework as proposed.

2.- Alternative sources in web format, usually provided by the UPM:

http://acer.forestales.upm.es/basicas/udfisica/asignaturas/fisica/default.htm

Remark: Proofs of formulas are not compulsory if the concepts are understood without the proofs.

Topic 0: Vectors and Vector calculus (only as a preparation for the other topics)

- Magnitudes and units: Types of magnitudes – Constituent vectors – Operations with vectors

Topic 1: Kinematics

- Kinematics : all "Basic concepts", except: Relative motion/Uniform rotation

Topic 2: Dynamics

- Particle dynamics : Newton's laws of motion, examples of forces
- System dynamics : Internal and external forces

Topic 3: Work and Energy

- Particle dynamics : Work done by a force, Kinetic energy of a particle, Conservative forces. Potential energy, Conservation of mechanical energy

Topic 4: Systems of Particles and Statics

- System dynamics : Center of mass
- Rigid body : Introduction, Rotation around center of mass (only "Static equilibrium")

Topic 5: Rigid Body

- Rigid body : Angular momentum of a rigid body, Rotation equation of motion, Moment of inertia, Rotational energy, Condition of rolling
- System dynamics : Angular momentum of a system

[etc.]

Figure 3. Suggestion of web pages as possible sources for the task required.

In the first portion of the course, before a mid-term exam, students were requested to do this type of homework without any monitoring by the lecturer. In the second portion of the course, this out-of-class activity was supervised by requiring a short summary that had to be presented at the beginning of class for a grade. The summary had to be handwritten, thus avoiding unproductive ‘copying and pasting’ from digital sources (e.g., Internet). Indeed, our sole aim was to compel students to make a thorough examination of the topic prior to the class, and this goal would not be reached if students blindly ‘copied and pasted’ digital texts without even reading them. For the same reason, we established rubric specifications for the summary that were simple and easy to meet but which encouraged students to conduct a more in-depth study of the topics scheduled. In detail, for each summary 0.25 points (out of 1) were given for addressing all the contents of the topic (according to Fig. 2 and 3), 0.25 points for scientific accuracy, 0.25 points for clarity of text, and 0.25 points for clearly explaining the formulas in a complete and correct manner. This simple rubric rendered grading simple as well. Examples of such handwritten summaries are presented in the Supplemental Material available online.

This remedial action can be deemed a type of `flipped’ or ‘inverted’ classroom, since its purpose is to transfer an essential part of the traditional knowledge transmission from the classroom to a previous class preparation at home. (Chen et al. 2014; Kim et al. 2014; Boronat-Navarro, Puig-Denia, and Fores 2016). Although the flipped technology is new, many approaches which are actually much older are being labelled ‘flipped’, since they meet a catch-all definition stated by Abeysekera and Dawson (2015).

However, most recent flipped-classroom approaches consist in delivering the theory contents previously to the class itself through such means as online lectures or video-recorded lectures posted online (e.g.: Blair, Maharaj, and Primus 2015; Baepler, Walker, and Driessen 2014; Calimeris and Sauer 2015; Trogden 2015; Wasserman et al. 2015) or at least a combination of online lecture video and textbook (Moraros et al.

2015). Yestrebsky (2015) used voice-recording over slides, resulting in more flexibility and lower costs. An account of other technologies used (automated tutoring systems, case-based presentations and simulations as well as face to face synchronous activities) is provided by O'Flaherty and Phillips (2015).

In contrast, our approach is not based on the aforementioned media, but rather on such media as textbooks and already existing, freely available web pages, which are more usual as independent or autonomous learning media, especially for life-long learning. In addition, a summary of the theory was delivered in class in the traditional way at the blackboard, besides the complementary activities (problem solving, Java simulations, quiz questions, etc.). Our 'flipped' approach is much more similar to that implemented by Winquist and Carlson (2014), using textbooks to read prior to class and giving a brief lecture (about 10-20 minutes) in class as a preparation for class activities.

An advantage of our flipped approach with such rather traditional media is the scarce additional costs, in contrast with the required funding in case of the flipped model with pre-recorded lectures and similar technological means (O'Flaherty and Phillips 2015; Brewe, Dou, and Shand 2018).

There are other similar proposals to engage students in topic-related activities prior to imparting lessons on a topic (Lorch et al. 2010; Siler, Klahr, and Price 2013). However, in these cases, the preparatory activities (problem-solving or experimental work) were not specifically oriented to theory content, and the populations of students were different from our population. In addition, problem-solving strategies are best taught in class rather than online as a preparatory activity prior to class (Trogden 2015).

Theoretical framework

This homework approach should address the lack of time that first-year engineering students devote to studying outside of class, which is clearly less than the amount recommended by the EHEA curricula. Teachers' complaints regarding students' spending too little time in out-of-class study are quite common; therefore, approaches have been established to increase out-of-class study time without external motivators (Fukuda and Yoshida 2013). Traditional homework can certainly be one of these external motivators. However, if appropriately managed and applying the approach suggested by these authors, homework can become a useful tool to increase out-of-class study time and to render that time more productive. According to the study by Vedder-Weiss and Fortus (2012) regarding motivation to learn science, there is a need to reorient homework away from goals that are external and related to the outcome of learning and move towards goals that are internal and related to the process of learning. The goal should be the development of the ability to learn as a key competence (Hoskins and Deakin Crick 2010), complemented by reinforcing the culture of effort, which should also be an integral component of another key competence, civic competence. The role of student effort has been analysed by Khachikian, Guillaume, and Pham (2011) in connection with students' time-on-task reduction and grade expectations.

All this requires a change from a teacher-centred learning environment to a student-centred one. In this new learning environment, the 'whole new teacher' acts as a coach rather than an expert (Goldberg and Somerville 2014), tending to implement an educational reform described not only in terms of 'pedagogy' or 'type of learning', but also in emotional terms such as 'trust', 'courage', and 'openness'. As in our case, such a learning environment becomes natural in a flipped-classroom approach (O'Flaherty and Phillips 2015). In this approach, time spent in class should capitalize on the social interactions between teacher as a coach and students, promoting deeper learning and development (Wasserman et al. 2015, Trogden 2015).

In addition, passive learning and the resulting gradual student disengagement lead to absenteeism problems, which require, among other things, helping students understand that the principal mode of learning is self-directed (Barlow and Fleischer 2011).

In this context, an important factor of learning achievement is the secondary-school background, i.e., whether students come from a baccalaureate (BAC) or equivalent school background or from vocational education and training (VET) or similar background. VET students have many more achievement difficulties, not only according to our own experience in Spain but also according to Aypay, Erdogan, and Sözer (2007), the vocational curriculum being often perceived as a limitation to further academic studies. Another efficiency divergence factor is the status of those students ('repeaters') who repeat the subject or the course (Cordero-Ferrera et al. 2011, Crow and Bailey 2015, Schutte 2016). These educational background differences are aspects specifically considered in our study.

Research questions and method

Research goal

In the following, the homework approach as an out-of-class activity will be referred to as 'homework' for the sake of simplicity.

This homework had the aim of fostering personal effort and active independent learning, as a mean to allow students to remedy educational background deficiencies and to benefit from the ensuing class, making the class a rewarding and interesting experience because of the students' improved understanding of theory.

Therefore, our primary research has addressed the perceived usefulness of homework for better understanding and a more appealing class. This does not allow a direct measure or evaluation of the Course Learning Objects via Student Outcomes, which is certainly a limitation of our research scope. However, this was research of an exploratory nature, similar to the studies by Sianez, Fugère, and Lennon (2010) and Lopes and Soares (2016), regarding engineering students' perceptions of different learning activities.

This research goal can be expressed in the following research questions. The first research question (1) merely plays an introductory role – it just attempts to examine the level of students' participation in following our proposal using percentage estimates:

(1) Which level of participation did students reach in completing the homework?

(2) To what degree of perceived usefulness did the homework create a better understanding of theory in class?

(3) To what degree of perceived usefulness did the homework help the students maintain attention in class by finding the class 'less boring'?

(4) To what degree were students interested in the homework, and what was the relation between degree of interest and perceived usefulness?

For practical reasons, these research questions should take the following three factors into consideration: control of the homework (i.e., whether the homework was monitored), secondary school background, and students' status as repeater (RE) or non-repeater (NR).

The sample

This study was conducted with 268 first-year students of fundamental physics at our engineering college in Spain.

Table 1 presents their distribution in groups according to the conditions of the preceding subsection concerning secondary school background and status as repeater or non-repeater. Regarding the first condition, the few students coming from the university access course for students over 25 years of age were included in the VET group (similar background). Of course, each individual student belongs to two of these groups: BAC or VET, and RE or NR. The percentage of repeaters (RE) was 28% in the BAC group and 44% in the VET group.

Table 1. Grouping of students according to their individual backgrounds.

Group abbrev.	Group description	*n*	sum
BAC	Students with baccalaureate or equivalent background	170	268
VET	Students with VET or equivalent background	98	
RE	Repeater	90	268
NR	Non-repeater	178	

The survey

For the reasons presented when introducing the research questions, the survey was conducted by means of the questionnaire annexed at the end of this paper. It was answered by the students anonymously by the end of the course (before the final exam).

Coding scheme, statistical test for data analysis, reliability, and validity

In the survey questionnaire, the majority of the questions had four possible answers, ranging from a minimum to a maximum. To obtain quantitative results allowing a comparison with the range mid-point, we assigned each answer an integer ranging from 0 for the first answer (e.g., ‘Not at all’) to 3 for the final answer (e.g., ‘A lot’) as a coding scheme (Likert scale) for questions Q3 and Q5 (see Annexe). Inversely, for Q2, the coding scheme ranged from 0 for the final answer to 3 for the first answer.

For Q4, the four answers were assigned an interest level from 0 for the first answer (i.e., homework not completed whether monitored or not monitored) to 3 for the final answer (i.e., homework usually completed, independent of control). For Q6, we assigned 0 to ‘No...’, –1 to ‘More [bored]…’, and +1 to ‘Less [bored]…’.

When calculating percentages of students, the criterion is stated before the corresponding result.

In the data analysis, confidence intervals procedures were applied to obtain statistical information about mean and proportion for the populations considered. Concerning the mean, a normal distribution of the data sample was assumed, variance was estimated and a Student’s t-distribution was used to calculate the limits of the confidence interval. Hypothesis tests were applied to determine whether a difference between parameters of independent populations (like baccalaureate and VAT students in this study) is significant or not. To be precise, a t-test and a z-test were used to compare two different means and two different proportions, respectively.

To ensure the reliability of the Likert-scale portion of the survey, we checked the necessary coherence among the answers to Q1, Q2 and Q3 as well as among the answers to Q4, Q5 and Q6. For example, if a student answered Q2 that he or she understood topics quite well before the class after having answered Q1 that he or she never previewed the topic before class, we can infer that he or she filled in the questionnaire randomly or without paying attention. These questionnaires were discarded, and the students involved were not included in Table 1. In addition, we conducted a one-way ANOVA with a cross-check of the statements on perceived usefulness and interest taken in the homework, as described in the subsection ‘Degree of interest in the control phase and relation to perceived usefulness’.

To check validity, in the next Results and Discussion section, we compare our results with previously published empirical results.

Comparative analysis of the grades for homework and exams

The preceding research, particularly when focused on perceptions, was based on students' statements in the survey questionnaire, which always have a subjective component. Therefore, a measure of the quality of the students' participation in our homework approach cannot be expected. However, as complementary research based on fully objective data, we have utilised the available individual grades for homework and exams. A comparative analysis of these sets of data should show whether the perceptions of usefulness expressed by our students are at least consistent with a possible correlation between the grades mentioned.

For this analysis, reported in a subsequent section, students were placed into two groups according to their individual homework grades (out of 0.5): an 'insufficient homework' group for homework grades < 0.25 and a 'sufficient homework' group for homework grades ≥ 0.25. Our analysis is based on the comparison of the 95% confidence intervals of the exams' mean grades for each group.

The grades of 318 students were available. This number includes not only the 268 students considered in our primary research based on the survey questionnaire but also those students whose survey questionnaire was discarded because of inconsistent answers and those students who did not complete the questionnaire at all. Because the survey was anonymous, it was not possible to match each valid survey questionnaire with the corresponding individual grades.

Results and Discussion

Level of homework completion as percentage estimates

The homework completion percentage in the no-control phase was estimated from the answers to survey question Q1. Here, we considered homework to be effectively completed only if it was completed regularly, i.e., ‘quite often’ or ‘always or almost always’, not ‘only a few times’. The percentage obtained was (24% ± 5%) at the 95% confidence level (95% CI).

The percentages for the control phase were estimated from the number of answers to survey question Q4 because the possible answers clearly indicate whether students did the homework in this control phase (Q4 will be considered again later). Thus, only the students who stated that after the non-control phase they ‘continued not to preview the topic before class’ in the new control phase, i.e., (2% ± 2%), were assumed not to have completed the homework in this control phase either. Indeed, the other students stated that they did the homework in the control phase either because of the compulsory delivery or because the students had been doing the homework previously and simply continued. The overall percentage of these students was (98% ± 2%) (95% CI) (Figure 4). Thus, monitoring the homework led to a substantial increase (74% ± 6%, 95% CI).

We agree that other manners of calculating these estimates (e.g., using more restrictive criteria) could provide somewhat different percentages although not significantly different. However, the conclusion is that the increase in homework completion during the control phase was important and reveals the relevance of monitoring homework.

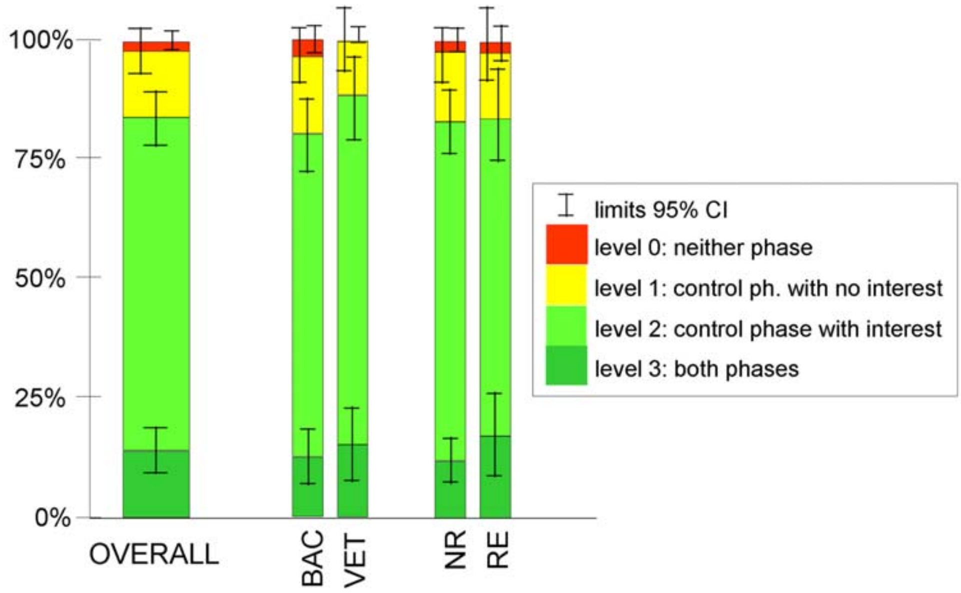

Figure 4. Percentages of homework completion in the control phase, both for the entire population and the different groups.

Between the BAC and VET groups, the differences both in the no-control phase (21% compared with 30%) and the control phase (96% compared with 100%) are statistically significant in favour of the VET group (p = 0.082 and p = 0.061, respectively). The difference for the other grouping (20% for NR compared with 33% for RE students) is clearly significant in favour of the RE students (p = 0.014) in the no-control phase but not significant (both 98%, p = 0.984) in the control phase.

An explanation for the difference in favour of the VET students is the awareness of their inadequate secondary education. This explanation is consistent with the previously mentioned phenomenon that the vocational curriculum is often perceived as a limitation to further academic studies (Aypay, Erdogan, and Sözer 2007) or a second-choice option for school dropouts (Masson, Baati, and Seyfried, 2010). Most likely, this awareness spurs VET students to work harder than their BAC classmates, who are often too self-confident. Although we have no empirical evidence of this explanation, we ourselves and colleagues in our college have observed this awareness, so that there is a clear need of making this topic the focus of future research.

A similar explanation could apply to the clearer significant difference in favour of the RE group over their NR classmates. Cordero-Ferrera et al. (2011) observed that the repeater status was a determining factor for poorer educational efficiency, and if such RE students are conscious of this weaker background, these students most likely try to work harder than their NR classmates. Indeed, our repeaters often say openly that they feel pressure to pass the course with no further repetition for two reasons related to the regulations of our university: a more expensive repeater matriculation and the possibility of not being permitted to complete their engineering degree. The last reason is also present in the situation described by Schutte (2016) for repeaters. This could explain a more intense effort by these students and there is a clear need of making this issue the focus of further research as well.

Perceived homework usefulness for a better understanding of theory in class

According to the answers to survey question Q3, the mean degree to which the homework helped students better understand theory in class in the no-control phase (perceived usefulness) was 1.84 ± 0.09 (IC 95%), i.e., clearly over a 1.5 range mid-point. The small differences between the BAC and VET groups and the NR and RE groups were not significant ($p = 0.337$ and $p = 0.470$, respectively).

In the control phase (survey question Q5), the corresponding degree was even higher, 2.05 ± 0.09 (95% IC). Again, there was no significant difference between the BAC and VET groups ($p = 0.919$) or the RE and NR groups ($p = 0.223$).

The higher degree for the control phase compared with the no-control phase can be explained by the fact that writing down a summary of a text demands more attention than only reading the text, rendering this preparatory homework more effective.

Perceived homework usefulness for maintaining attention in class

The degree of another perceived usefulness was extracted from survey question Q6. This is the degree to which students perceived the next class as ‘less boring’ because the preparatory homework helped them maintain their attention. The overall mean value was 0.14 ± 0.08, i.e., slightly over 0 or least boring (Figure 5). The difference between the BAC and VET groups (0.03 compared with 0.32) was clearly significant ($p = 0.001$) in favour of the VET group. Conversely, no significant difference between the NR and RE groups was identified ($p = 0.381$).

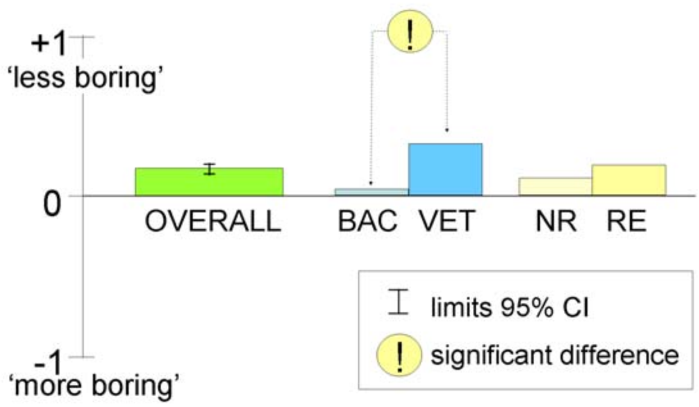

Figure 5. Perceived usefulness in the control phase to sustain attention in class.

As an overall mean result, these results indicate an additional usefulness of our homework approach: to become ‘less bored’ in class, i.e., to be more attentive.

However, in our opinion, the most interesting information derived from this open-ended question lies in the reasons given (omitting some responses that did not sound genuine, but rather stereotypical):

Typical reasons for becoming more bored: ‘I already knew the theory topic’; ‘I already knew almost everything’; ‘I already knew what was being explained’.

Typical reasons for becoming neither more nor less bored: ‘The questions I had were explained’; ‘It was useful to review the knowledge I had before’; ‘I tried to understand the theory better’; ‘I could compare the things in the homework with what occurred in class’.

Typical reasons for becoming less bored: ‘I already knew more or less about the theory topic’; ‘I knew what was being dealt with’; ‘The stuff at the blackboard sounded somewhat familiar to me’; ‘I wanted to understand the questions that I had before the class’.

The reasons for becoming more bored are similar to the reasons for becoming equally or less bored. For example, ‘I already understood the theory topic’ as a reason for becoming more bored is quite similar to ‘I already more or less understood the theory topic’ for the reverse. This indicates other factors involved in maintaining attention in class. Such answers indicate a development of students’ self-confidence, which is strongly related to enabling students to become autonomous learners (Macaskill and Denovan 2013).

Degree of interest in the control phase and relation to perceived usefulness

As described in subsection ‘Coding scheme, statistical test for data analysis, reliability, and validity’, by means of survey question Q4, we inferred the level of students’ interest in the homework.

The overall mean interest level was 1.95 ± 0.08 (IC 95%) (Figure 6). This is consistent with the percentage estimates based on the same survey question (Figure 4).

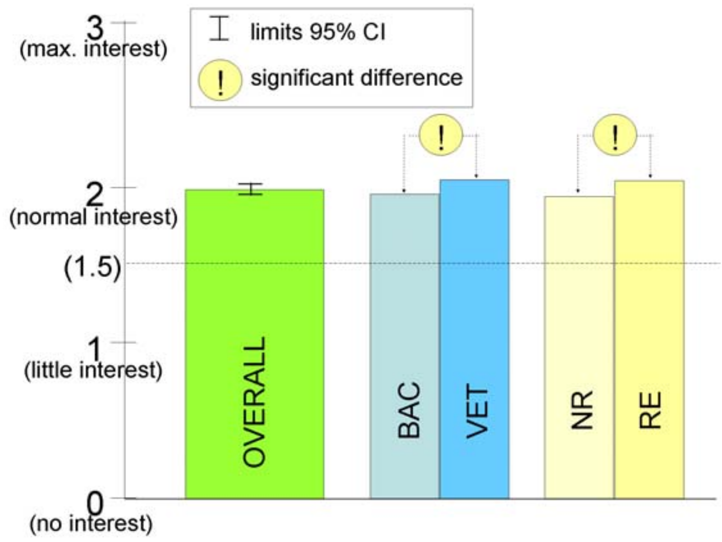

Figure 6. Degree of interest taken in the homework in the control phase by all students and by the different groups.

The difference between the BAC and VET groups (1.9 compared with 2.0) is small but significant (*p* = 0.042) in favour of the VET group. The same is true for the NR and RE groups (also 1.9 compared with 2.0) in favour of the RE group (*p* = 0.062).

An amazing but gratifying result was that a great percentage of students did the homework only when controlled, but then became remarkably interested (Figure 4, interest level 2). From the context of the question, it can be inferred that the control component of our homework approach led to greater motivation. The small but significant differences in favour of the VET group and the RE group can be explained as in the subsection ‘Level of homework completion as percentage estimates’.

To determine whether the perceived usefulness changed as a result of the interest taken in the controlled homework completion, we conducted a one-way ANOVA. For students as a whole, the first type of perceived usefulness (understanding theory better in class) was relatively linked to the interest taken in the homework as shown in Table 1: the students with a low degree of interest (level 1) perceived clearly lower usefulness compared with the students with normal or maximum interest (levels 2 and 3). The difference is clear with $p = 0.000$, and there is no overlapping between the 95% confidence intervals for interest level 1 and the higher interest levels 2 and 3. The results restricted to the single groups are similar to these overall results (with p-values of 0.000 for the BAC group, 0.001 for the VET group, 0.000 for the NR group and 0.011 for the RE group).

Table 2. Relation between interest taken in the homework and perceived usefulness to better understand theory in class (values out of 3, with 95% confidence interval, for all students).

Degree of Interest	*n* (students)	Perceived usefulness (understanding) (out of 3)
Level 1 (low)	36	1.4 ± 0.2
Level 2 (normal)	182	2.15 ± 0.09
Level 3 (maximum)	35	2.1 ± 0.2

This positive relation between degree of interest and perceived usefulness for a better understanding of theory in class was to be expected because interest leads to paying more attention and hence to developing a better background for understanding explanations in class. In fact, this is in an additional check of the reliability of the Likert-scale portion of the survey, as mentioned in the subsection ‘Coding scheme, statistical test for data analysis, reliability, and validity’. This result is also consistent with a similar relation observed by Zhu and Leung (2012) between the amount of time spent on homework and achievement if we establish a parallel between interest taken and time spent on the homework and understanding theory in class and achievement. These results are also similar to the results of Snodin (2013). Kingir et al. (2013) concluded that in a classroom environment supporting student autonomy, students tend to develop greater interest and use more self-regulatory strategies.

Conversely, Bednall and Kehoe (2011) observed that directing students to summarise passages of text (an essential homework component of the control phase) failed to improve learning. However, the population in that study were all demonstrably proficient students (in the top 25% of their cohort), which does not apply in our case. These authors also verify the positive effect of the prompt feedback resulting from the nearly immediate comments and marking of each homework piece, as occurred in our case.

The second type of perceived usefulness (increased attention in class) does not depend on the interest taken in the homework, with $p = 0.413$ and a total overlapping of the 95% confidence intervals. This result extends also to the different groups (BAC compared with VET, NR compared with RE).

Complementary results from the analysis of homework and exam grades

The results presented in the preceding section are based on the students' own statements in the survey questionnaire, which always have a strong subjective component. Therefore, as more objective data, we have used the available individual homework grades (out of 0.5) and final exam grades (out of 10). The grade analysis was conducted as described in the subsection 'Comparative analysis of the grades for homework and exams' and provides the results shown in Figure 7 as an insufficient compared with a sufficient homework histogram. The two 95% confidence intervals of the final exam indicate that grades are clearly different, with mean values of 5.5 ± 0.3 (95% CI, $n = 205$) for the sufficient homework group and 2.3 ± 0.2 (95% CI, $n = 113$) for the insufficient homework group. This is certainly not a measure of the quality of the students' participation in the homework approach, but this objective difference in favour of the first group is consistent with the students' perception that the homework approach was useful.

The significant better performance in the final exam of most students in the sufficient homework group is a similar result as that reported by many authors quoted above referring to flipped-classroom approaches – for example Yelamarthi and Drake

(2015), O'Flaherty and Phillips (2015), Winquist and Carlson (2014) (although with some limitations), Baepler, Walker, and Driessen (2014) (with learning outcomes at least as good as those in the traditional classroom and in one comparison significantly better), Calimeris and Sauer (2015), and Trogden (2015). In contrast, Wasserman et al. (2015) report neither gain nor loss (over the traditional counterpart) on more procedural problems and small to moderate gains on conceptual exam problems, with differences becoming increasingly pronounced as the instructor learned more about how to utilize the strategy. However, we have to admit that in general, the performance results from these flipped classroom approaches using pre-recorded lectures are generally better than those from our type of flipped approach using textbooks and web pages which were not specifically tailored for a flipped classroom. In contrast, the use of these rather traditional materials minimizes costs in time and resources. They are also more similar to the sources for a future autonomous life-long learning.

Because of the anonymous nature of the survey questionnaire, it is not possible to use this grade analysis to compare VET with BAC students although some details are also consistent with other results in the preceding section. In Figure 7, there is a remarkable overlapping of both intervals. Indeed, a number of students with good homework grades had poor exam grades. This is consistent with the number of students (approximately 14%) who in the survey questionnaire (question Q4) reported writing the homework summary 'mechanically, without paying attention…', i.e., without much interest (subsection 'Degree of interest in the control phase and relation to perceived usefulness'). In addition, we do not propose that our homework approach is a guarantee of learning because other individual factors may also play a role. This result is also consistent with the findings by Yestrebsky (2015) for a flipped-classroom approach – this author reports that the good and average performing students were aided by this teaching method, compared to the traditional teaching format, but that was not the case for lower performing students. Also, Blair, Maharaj, and Primus (2015) report that fewer students in their flipped classroom achieved highest-level grades, with no significant change in relation to average cohort exam performance. In addition, Moraros et al. (2015) report that 80% of their students found the flipped classroom model to be either somewhat effective or very effective, but this perceived effectiveness had no significant association to the performance as measured by the final grade. Chen et al. (2014) also report that their flipped approach was effective, with satisfied and highly motivated students with a better performance, but some students retained their passive learning habits.

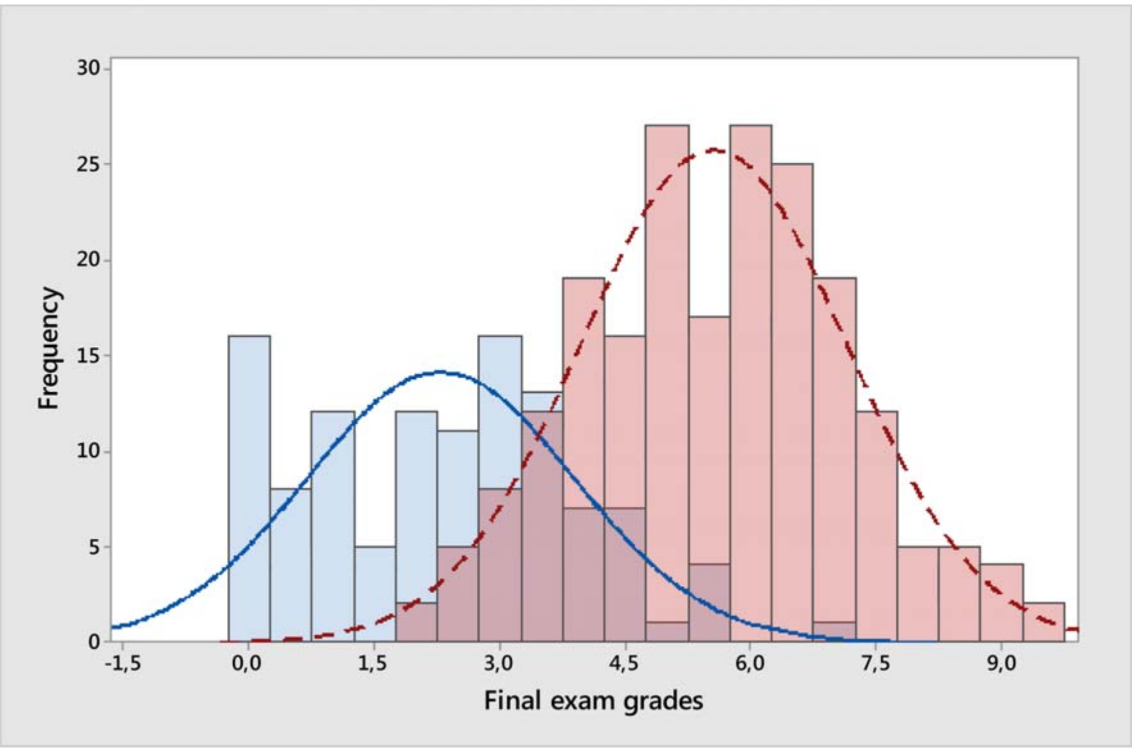

Figure 7. Insufficient compared with sufficient homework histogram with the intervals of the final-exam mean grades for each homework assessment group of students (solid line and light grey (blue in the online version) = insufficient homework group; dashed line and grey (salmon pink in the online version) = sufficient homework group).

In our case, there are a small number of students with insufficient homework assessment and acceptable or even good final exam grades. In one case, the exam grade was 7.2 (out of 10) with no homework delivery at all (homework grade of zero)! This simply indicates that our homework approach is not required for a successful exam because other individual factors may also play a role.

By contrast, no relation was observed between homework grades and mid-term exam grades, i.e., there is a total overlapping of both sufficient and insufficient homework histograms, with no significant differences between mean exam grades. This is consistent with the results in the subsection ‘Level of homework completion as percentage estimates’ because before the mid-term exam, the homework was not controlled (no-control phase). The low percentage of homework completion in this no-control phase is indeed consistent with the lack of a relation between grades on mid-term exams and homework.

Conclusions

The results of the preceding sections can be summarised as follows:

The attempt to learn autonomously in preparation for the next theory class is a useful homework approach for improved understanding of theory in class and sustaining attention in class.

However, it is essential to monitor this homework by having students submit a summary before each theory class although the requirements of the summary are quite easy to meet. Not only did the fulfilment percentage increase dramatically but also the perceived usefulness in the form of improved understanding of theory in class became remarkably higher, with slightly but significantly better exam grades.

Depending slightly on whether homework was monitored, the difference in doing this homework was not large but was statistically significant in favour of the VET students over their BAC classmates and in favour of the RE students over their NR classmates.

The compulsory summary awakened the students' interest, expressed in the attention the students gave to the homework. There was also a small but significant difference in favour of the VET group.

The interest shown in the homework was positively connected with its perceived usefulness for improved understanding of theory in class in students as a whole and in each group. Conversely, no connection could be identified with the perceived usefulness for sustaining attention in class (becoming less bored).

The results about the favourable perception are similar to those reported by the most authors quoted above for comparable 'flipped' approaches – for example Wanner and Palmer (2015), whose students preferred this type of blended learning and enjoyed the increased flexibility in their learning; Yelamarthi and Drake (2015), with a significant improvement in students' perceptions of their learning experience; O'Flaherty and Phillips (2015), whose students generally reported positive perceptions, except for a significant minority having some negative views (as in our case); Baepler, Walker, and Driessen (2014), with an improved perception of the learning environment; Kim et al. (2014), with students generally satisfied and agreeing in many cases that the class time interaction was helpful to their understanding of concepts, and Magana, Vieira and Boutin (2018) for lightly active but structured learning methods. In contrast, Wasserman et al. (2015) report mixed perceptions: while their flipped students perceived increased communication during class, their traditional counterparts perceived a more effective use of class time, despite less performance gains.

From the lecturers' point of view, this out-of-class activity had advantages and drawbacks. As an essential advantage, the entire scheduled syllabus could be covered with no stressful fast-paced lectures, which addresses the problems mentioned in the Introduction. A similar result is reported by Yelamarthi and Drake (2015), with a significant increase in course content with a flipped first-year engineering course. In addition, the theory classes were more lively, with sufficient time left for complementary activities such as Java simulations, short physics videos or quiz questions. This experience was also rewarding because of the interest shown by many students in preparing their summaries. One drawback was facilitating the possibility of students' delivering the handwritten summaries online as scanned files for grading because some students could not attend all theory classes because of illness or occasional employment duties. In addition, some large classes (over 40) made the assessment of homework summaries too time-consuming despite the simple rubric for grading, as mentioned at the end of the section 'A remedial action: a special homework to foster independent learning'. Indeed, the main concern of higher education teachers about this type of flipped approaches is the time commitment (Wanner and Palmer 2015), which should be kept within acceptable limits. A remedy to both drawbacks could be the approach adopted by Winquist and Carlson (2014), in which instead of our handwritten control summary, students had to answer embedded reading questions online prior to class.

In any case, the foregoing advantages as well as the perceptions reported by the students render our approach worthy of consideration as a promising practice on the local level as a remedy for levelling up the different secondary educational backgrounds and developing the competence for life-long independent learning.

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Annexe: Survey Questionnaire

Preliminary questions:

a) Which was your previous education or training before entering university?

☐ VET ☐ Baccalaureate ☐ Access for students over 25 years of age
☐ Other (please specify): ________________________

b) Are you repeating this subject? ☐ Yes ☐ No

At the beginning of the course, you were requested to review the topic scheduled for each class <u>before the class</u>. For this review, you had references and Internet links available at the Digital Campus.

<u>**Before the mid-term exam**</u>, it was not yet compulsory to deliver a handwritten summary.

Q1: How often did you review the scheduled topic before the class at that time?

☐ Never ☐ Only a few times ☐ Quite often ☐ Always or almost always

Please answer the two following questions only if you did not answer 'Never' to the previous question:

Q2: On the days you previewed the topic before class, did you understand it well in the textbook or the web site used?

☐ Yes, I understood virtually all of it.

☐ I understood it quite well, and I had only some confusion at the end.

☐ I did not understand it very well, and I had many questions at the end.

☐ I understood virtually nothing.

On the days you previewed the topic before class, do you believe the preview helped you understand the topic better in class?

☐ Not at all ☐ A little ☐ Quite a lot ☐ A lot

<u>After the mid-term exam</u>, it was compulsory to deliver a summary of the previewed topic at the beginning of class.

Q4: Was this compulsory nature the primary reason you previewed the scheduled topic before class?

☐ No, because I continued to not preview the topic before the class.

☐ Yes, but I wrote the summary mechanically, without paying attention to what I was writing.

☐ Yes, and I made the most of it to focus on what was scheduled for the class.

☐ No, because I was already previewing the scheduled topic before the summary became compulsory.

Please, answer the following two questions only if you attended at least two classes in which you handed in the summary at the beginning of class:

Q5: Did the summary help you to better understand the topic when the topic was explained at the blackboard?

☐ Not at all ☐ A little ☐ Fairly well ☐ A lot

Q6: In the classes in which you handed in the summary at the beginning of class, were you more bored or less bored than usual?

☐ No, neither more nor less, because ___________________________________

. ☐ More, because ____.

☐ Less, because ____